LS-227

Interlock and Control Systems for a Sector at the APS

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Overview of Interlock and Control Systems for a Sector at the APS

I. INTRODUCTION

This report describes some basic elements of the various Interlock and Control Systems associated with the Front Ends and Beamlines. Some systems serve only the Front Ends; other serve both the Front Ends and the Beamlines, while the Experimental Controls are for the Beamlines only.

Specific system requirements and design specifications are not in the scope of this report. They will be presented in the descriptions of the Experimental Floor Personnel Safety System (XF-PSS or, more often, PSS) and Equipment Protection System (XF-EPS or EPS), which will expand on the overview presented here.

The main focus here is on the PSS and EPS in the context of their interactions and interface to the Storage Ring Access Control Interlock System (ACIS), and Ring Controls. The other systems are only mentioned to make the cross section complete.

This paper is the first in series of three reports that jointly provide a full description of sector interlocks. The second report describes the PSS, and the third - the EPS.

II. FUNCTIONS OFF INTERLOCKS AND CONTROLS

- To provide feedback to the photon beam steering system
- To provide a proper collimation
- To provide biologically safe conditions on the experimental floor
- To provide shuttering and hence absorption of the full power of the beam and/or bremsstrahlung during injection and/or upon vacuum failure
- To isolate the Front End from the Ring under any vacuum failure scenario
- To help scientists with running their experiments

The 'Separation of Functions' diagram in Figure 1 illustrates how various systems relate to each other.

Sector Interlock & Control Systems

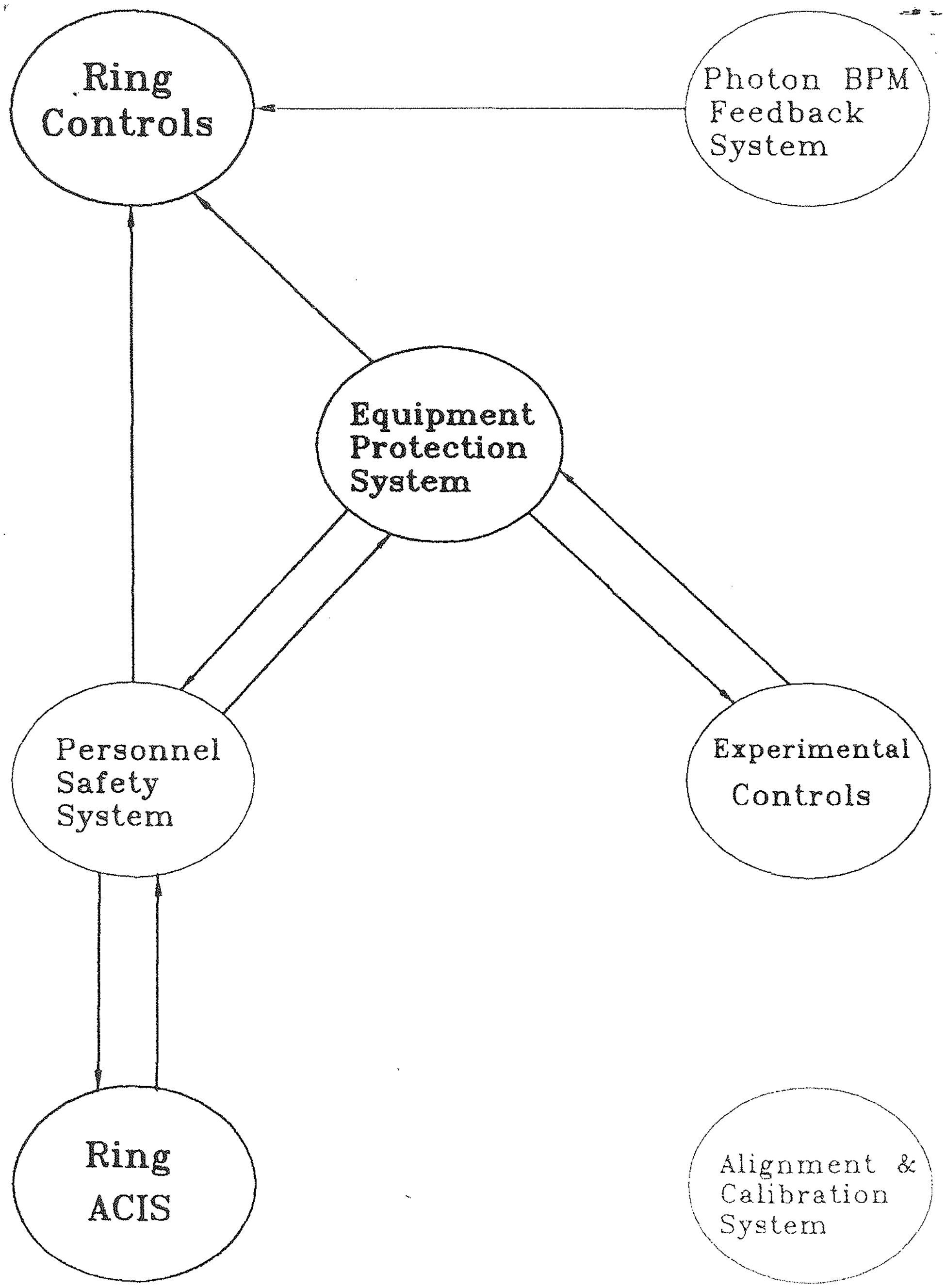

Fig. 1 Separation of Functions

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III. DESIGN PHILOSOPHY

Systems described below are independent, each is assigned to perform its primary function. Each system has exclusive control over the Front End/Beamline devices connected to it. When a system needs to manipulate a device over which it does not have exclusive control, it exercises the control via that device's exclusive controller.

To accomplish that, systems exchange a limited number of well-defined discrete signals, which are hardwired. These interfaces should be as few and as simple as possible.

The possibility of conflicts between various systems is eliminated by differing functional priorities. The PSS has the highest priority, followed by the EPS, and the Experimental Controls have the lowest priority.

IV. THE SYSTEMS

Figure 2 (on page 6) depicts the systems associated with each Sector and the devices and functions they serve.

To accomplish the above goals, each Sector is equipped with the following five control systems:

1. **Photon BPM Feedback System** (Fig. 3) - Feedback from the Front End beam position monitors (BPMs) will allow continuous adjustment of the beam position as necessary. In order to keep the photons within the required space-phase envelope, the steering system will control the power supplies of four bump magnets. The BPM currents will be wired to a Ring Input/Output Controller (IOC). The IOC is a VME/VXIbus-based computer system; it will interface to the Ring Ethernet via a transition module in the IOC enclosure. Experimenters have access to the information provided by the Front End (FE) and Mono BPMs through an Ethernet branch for the Sector.

2. **Alignment and Calibration System** (Fig. 4) - This is a portable PC-based stand-alone data acquisition and control system. It is used to control photon BPM (PBPM) and positioning table stepper motors as well as to read beam current signals. The primary goals are to position, calibrate, and diagnose the BPMs, and to align Front End and Beamline components. The system is not networked.

It is very likely that the system will eventually be VME/VXIbus based. It will then use software routines available under EPICS. At the present time the development is under way, and things look most promising.

3. **Experimental Controls** (Fig. 5) - are to be developed by the users. As shown in the drawing, the system controls and gets input from beamline devices associated with the experiment (e.g., slits, mono BPMs, mirrors, etc.), as well as experimental equipment in the hutches - motion systems, detectors, and other components. EPICS software tools developed by the APS-ASD Controls Group could be adopted for running the experiments. If this is the case, IOCs running under VxWorks will monitor and control the devices, either directly or through IEEE-488 and RS232C subnets. A SUN SPARCstation running under UNIX is also associated with each hutch. The workstation will provide operator interface (OPI) with the experiment itself and will be a platform for programming, data storage, trend analysis, and coordination with other experimental hutches in the Sector, just to mention a few of its functions. All Sector IOCs and OPIs connect to an Ethernet subnet for the Sector.

4. **Equipment Protection System (EPS)** (Fig. 6) is a single-chain PLC-based system. It consists of A-B's PLC-5/40 processor, local and remote I/O racks, field devices, and video control panels (VCP). The EPS monitors a variety of sensors - vacuum, flow, temperature, air pressure, and it controls field devices directly connected to it (e.g., valves). The VCP will provide an interface between the PLC and the operator. Data Highway Plus LAN links local processors with a DOS computer for centralized programming and troubleshooting. Front End status display is brought to the Control Room via EPICS - Experimental Physics & Industrial Control System software toolkit. Under certain abnormal conditions, EPS will immediately insert Front End shutters and may also dump the Storage Ring as, for instance, in the event of a vacuum collapse in the Front End.

   All Beamline and experimental components that are not part of the experiment itself will be wired to PLC I/O modules. The PLCs are most suitable for implementing hardware interlocks, sequencing, and system coordination. Maintenance and testing routines will also be programmed into the PLC. The EPS is dedicated to monitoring, controlling and interlocking Front End and Beamline hardware (thus allowing user controls to run the experiment and higher level requests and procedures without being impacted by the routine Beamline operation).

   Each Front End is equipped with an Eaton IDT PanelMate VCP - a color-graphics CRT-based device that replaces hard-wired input and output devices found in "conventional" panels. A high-resolution monitor displays all control data. It is configured to give an operator instant recognition of the status of all interlocks as well as the state of various devices in Front Ends and Beamlines (e.g., valves, shutters, flow, pressure, etc.). The device also provides windows for error messages and alarms. Alarms, messages, and displays are all hierarchial, and easily configured. PanelMate (PM) generates its own documentation. Monitoring and control are in real time. To be fully operational, PM requires only a single serial cable to connect to a PLC. The VCPs will prove to be invaluable in trouble-shooting interlocks and testing hardware and software components of the EPS.

5. **Personnel Safety System (PSS)** (Fig. 7) is a doubly redundant PLC-based system. It is built around Allen-Bradley's PLC-5/30 Programmable Logic Controllers. Safety hardware for the hutches, and photon and safety shutters are wired into both interlock chains. Each interlock chain is capable of inserting Front End partitions should an unsafe situation develop. Each Sector is provided with an independent PSS - no data communication links to other control systems or Sectors. The only exception to that is the one-way PLC-to-VME data transfer for PSS status reporting in the main control room. More on that in the "Experimental Floor Personnel Safety System".

Red - PSS
Blue - EPS
Magenta - Photon BPM Feedback Sys.
Cyan - Alignment & Calibration Sys.
Green - Experimental Controls

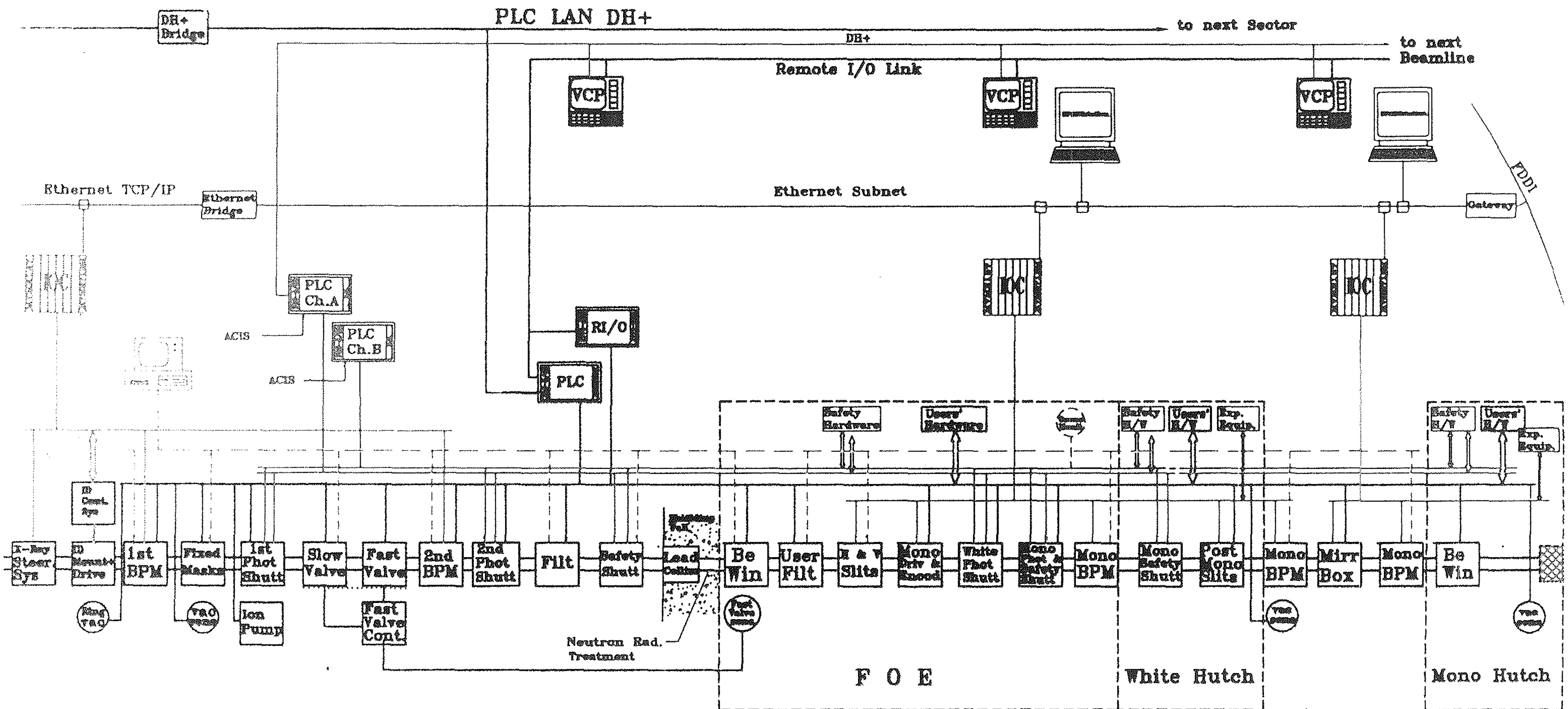

Fig. 2 Functional Diagram of the FE/Beamline Interlocks & Controls

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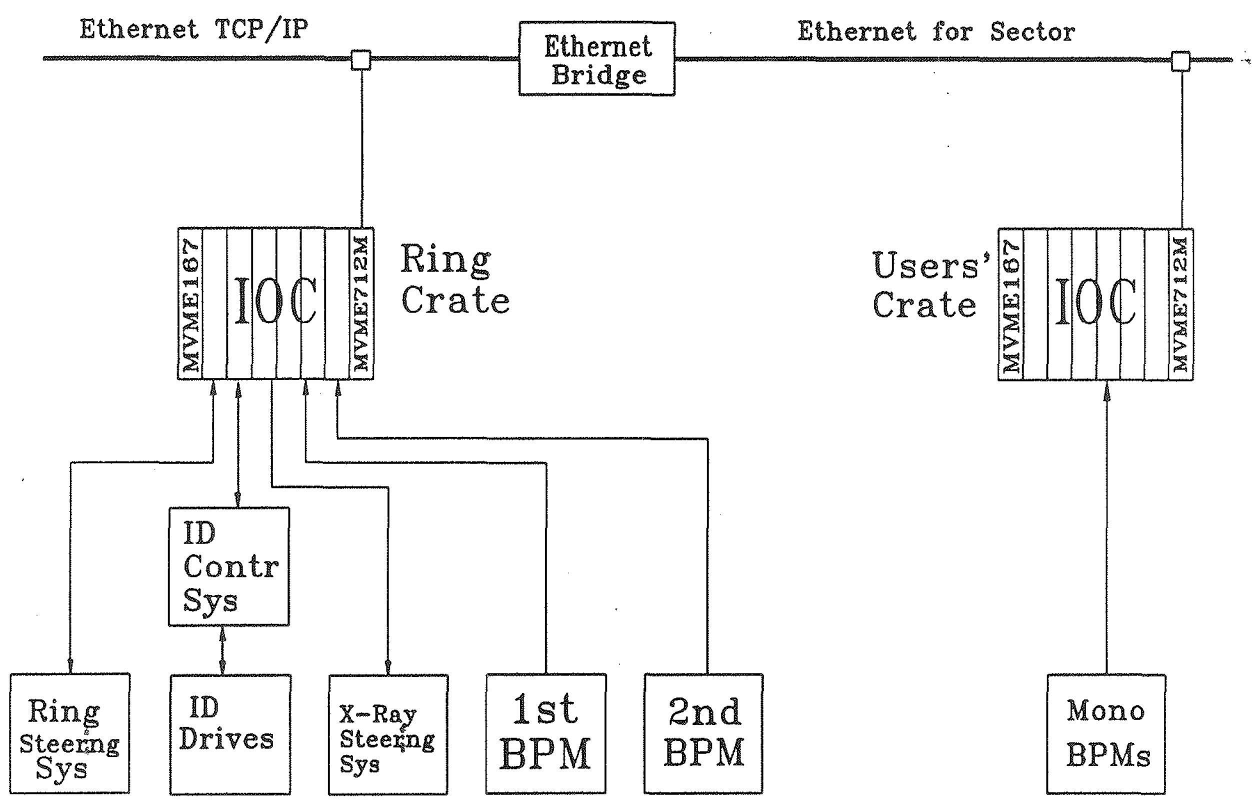

Fig. 3 Photon BPM Feedback System

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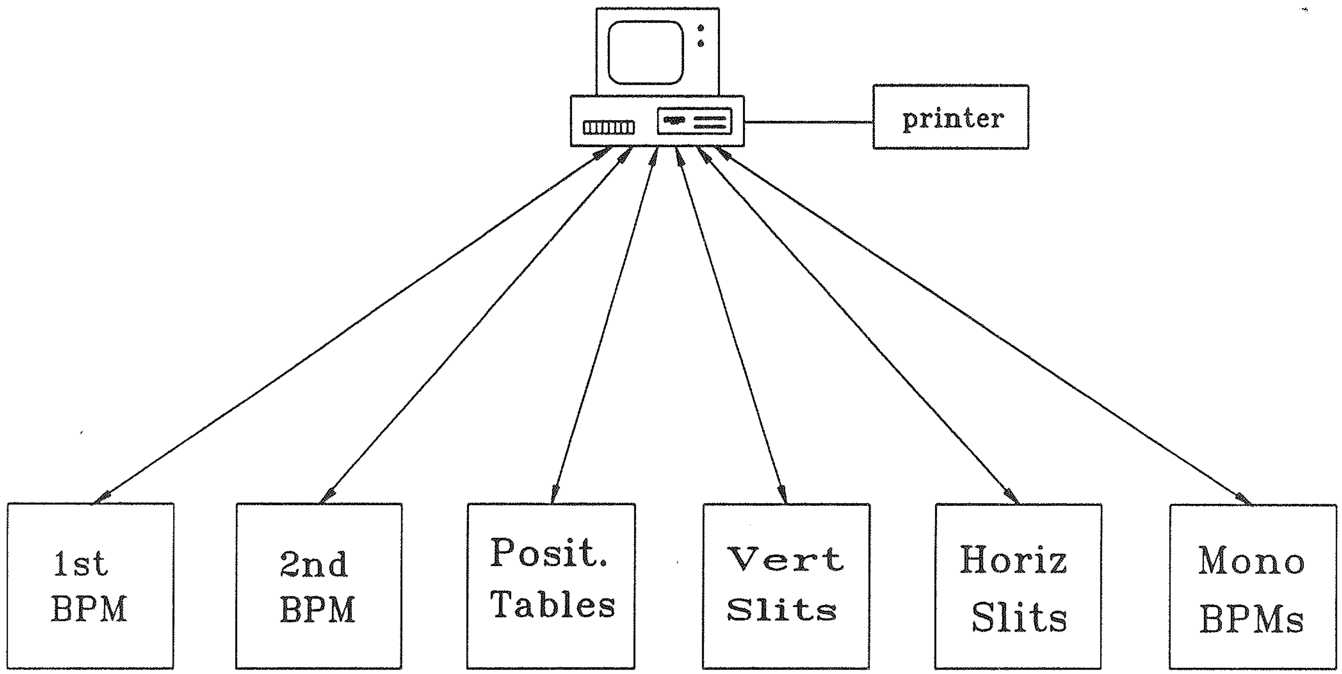

Fig. 4 Alignment & Calibration System

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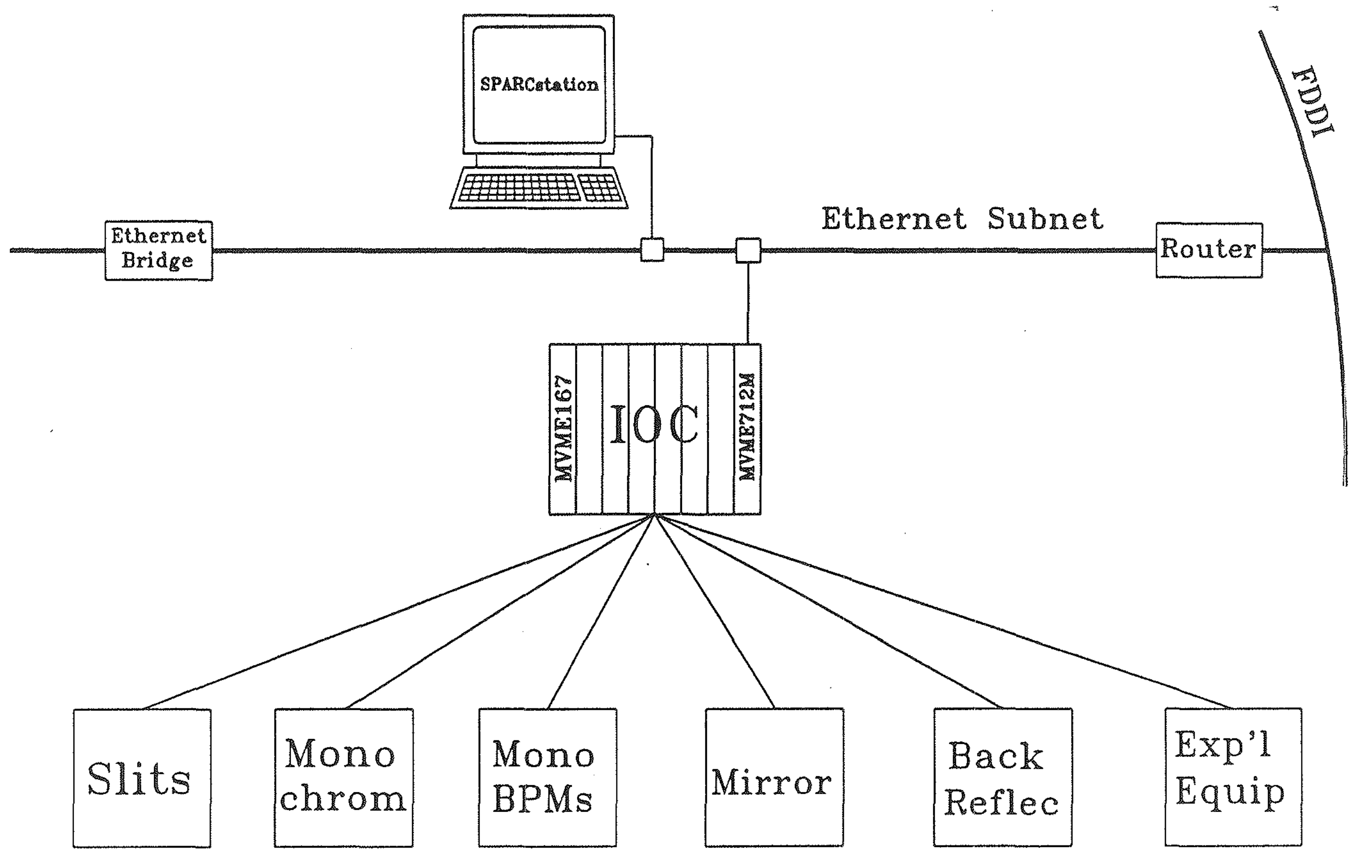

Fig. 5 Experimental Controls

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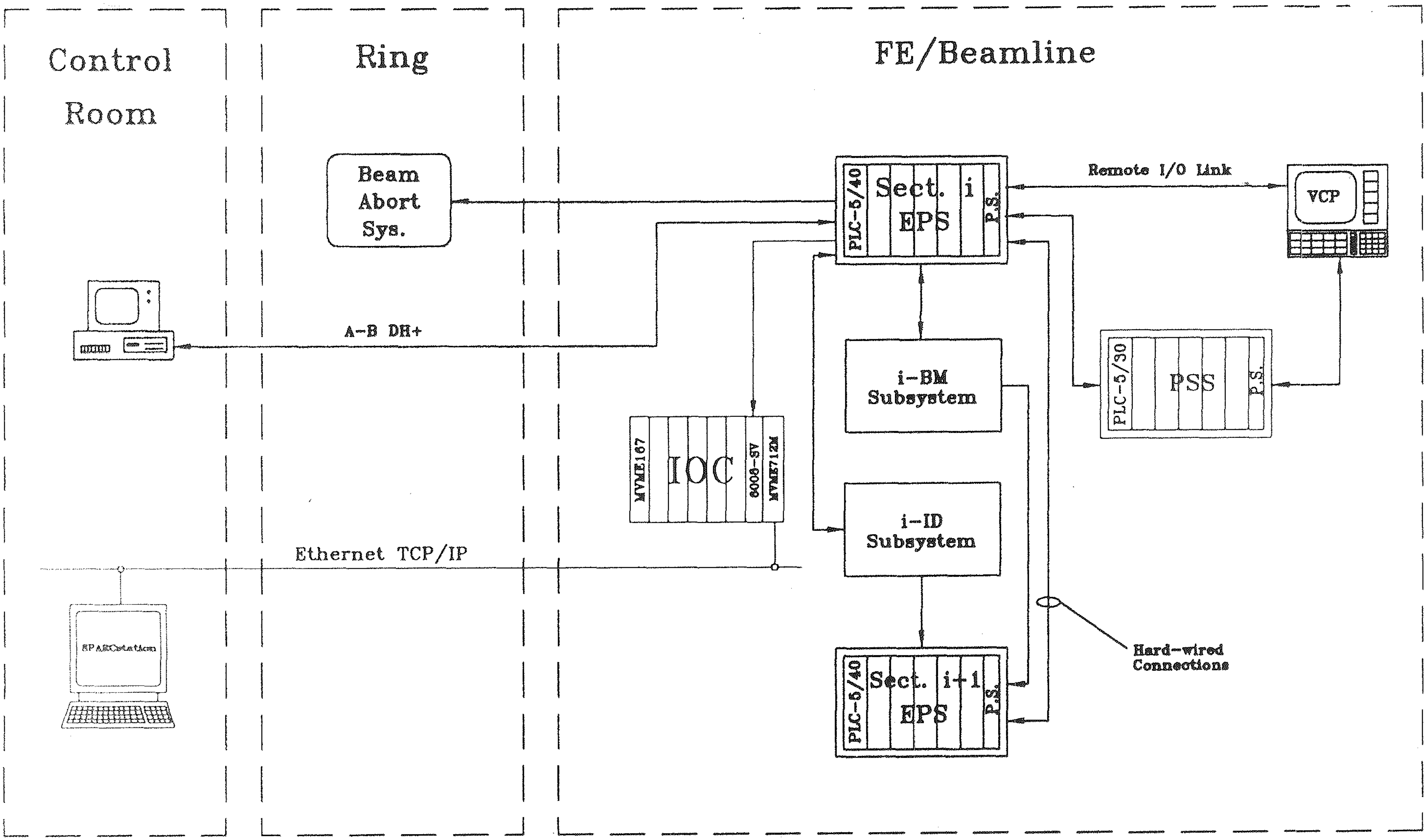

Fig. 6 **APS Experimental Floor Equipment Protection System PLC Layout**

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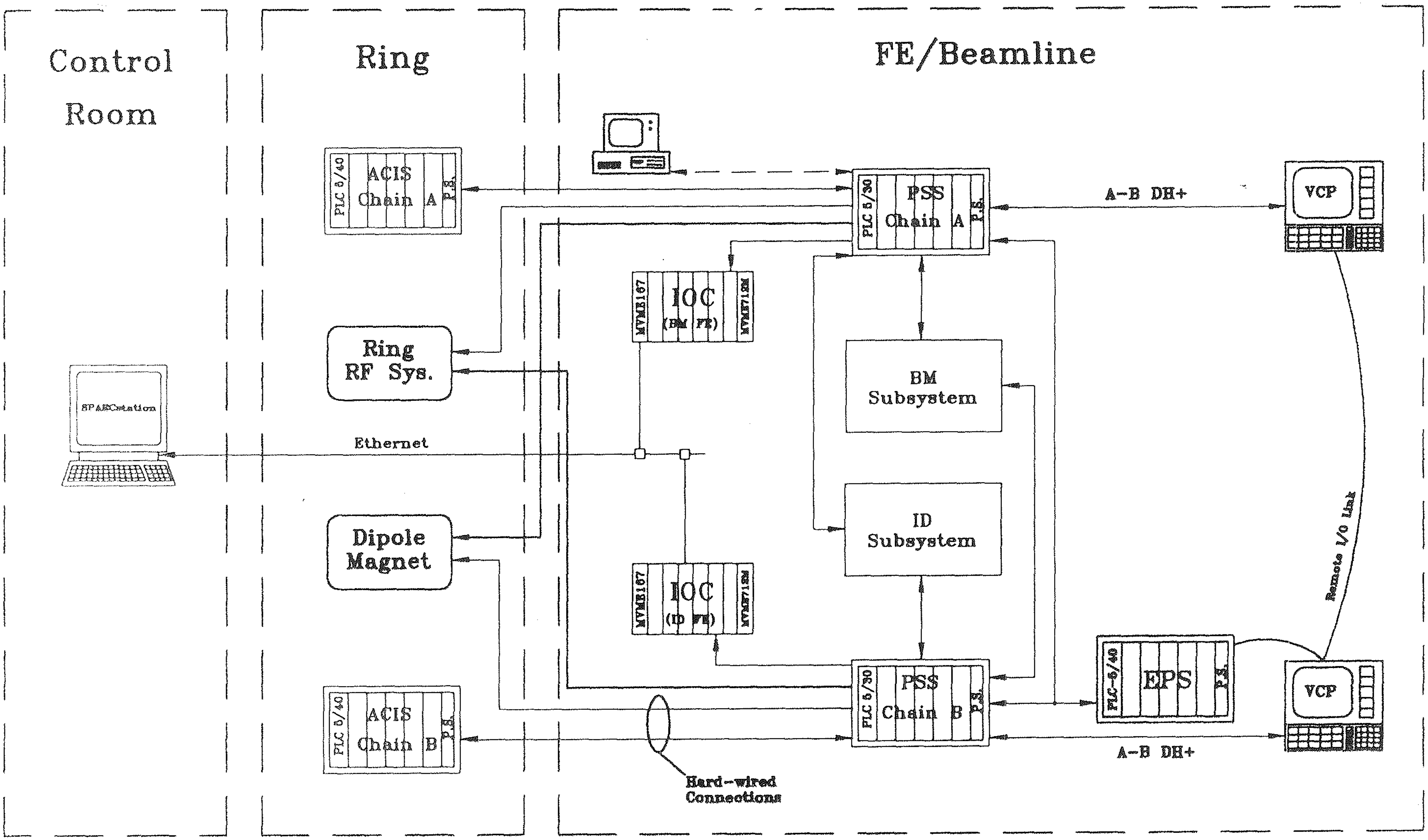

Fig. 7 APS Experimental Floor Personnel Safety System PLC Layout

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V. INTERACTION BETWEEN SYSTEMS

The overall safety of Sector operations is realized through the Experimental Floor Personnel Safety System (PSS) and Equipment Protection System (EPS). These systems are autonomous. Each is capable of performing its primary function by monitoring and controlling beamline and hutch instrumentation directly connected to it.

At the same time, it is necessary for the systems to exchange information through a limited number of well-defined interfaces. The PSS also interfaces to the Ring ACIS at each ratchet of the shielding wall. Both PSS and EPS interface to the Ring Controls for the purpose of beam dump and reporting status information to the main control room.

Interfaces between systems are few, simple, and hardwired. By keeping the number of interfaces to a minimum, the independence of individual systems is enhanced, and hardware and logical complexity is reduced.

1. Interface between XF-PSS and Storage Ring ACIS[1]

The main goal of the PSS-to-ACIS interface is to make it possible to run the Ring while any Sector's PSS is not available for use, for whatever reason. To achieve this, ACIS is provided with the capability to monitor and control Front End shutters.

The XF-PSS interfaces to the Storage Ring's ACIS at each Front End as shown in Figure 8.

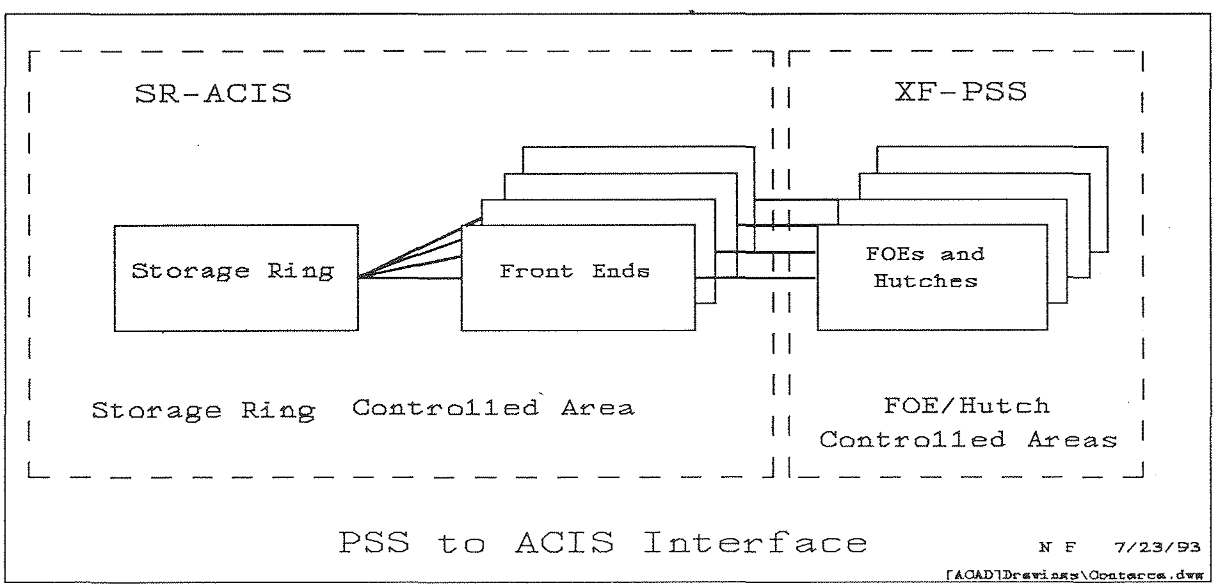

Fig. 8

All inter-PLC signals pass through relay contacts to eliminate common ground problems. The signal are failsafe (e.g., the relays must be energized to assert a safe condition).

Beamlines are radiologically isolated from the Storage Ring by two Safety Shutters, SS1 and SS2, and the Second Photon Shutter - PS2 located in the Front End . When these three shutters are closed, personnel may safely work in the First Optics Enclosure (FOE) and Hutches even with beam in the Storage Ring.

With respect to the Storage Ring, a Beamline's PSS is considered complete if PS1, SS1, and SS2 are closed or the PSS's interlocks are made up. If all shutters are closed, PSS may be functionally tested.

Because Front End shutters are the key devices to isolate the Beamlines and the Storage Ring, their positions are independently verified by both interlock chains.

1.1. PSS/ACIS Signal Definition

The following signals are implemented in both interlock chains.

1.1.1. ACIS PLC to PSS PLC:

a) **Front End Shutter Control**
When this signal is denied by the ACIS, PSS automatically inserts the shutters. When asserted, shutter control is released to the PSS and the shutters can then be opened at will by the Beamline operator provided all PSS interlocks are satisfied. ACIS can close the shutters (PS2 and both Safety Shutters) but cannot open them.

b) **ACIS Status**
When asserted, ACIS is in the Beam Permit mode. Otherwise, ACIS is in the Restricted Access mode, the Controlled Access mode, or has faulted.

c) **Storage Ring Status**
Asserted signal indicates that there is no e^+ beam in the Storage Ring. Otherwise, PSS assumes that beam is stored and being injected into the Front Ends.

1.1.2. PSS PLC to ACIS PLC:

a) **PSS Status**
Assertion signifies that PSS logic is satisfied. If shutters are closed, personnel may enter the First Optics Enclosure (FOE) and hutches. If FOE and hutches are verified free of personnel and locked, FE shutters may be opened. If this signal is 0, for whatever reason (e.g., processor fault), ACIS immediately inserts PS2, SS1, and SS2.

b) **PSS OK to Fill Storage Ring**
This signal must be asserted to allow Storage Ring periodic refill. Denial of the signal by the PSS will not interfere with the run underway. However, injection of new positrons into the Storage Ring will be prevented until the problem is corrected, and the signal is reasserted. This, of course, is not applicable to the top-off mode of operation.

1.2. Shutter Status to PSS and ACIS

This status consists of three signals dependent on the position of the Front End Photon and Safety Shutters. When a Front End or a Beamline is OFF LINE, assertion of three signals is needed to declare the shutters closed - both Safety Shutters and a Photon Shutter. Denial of any one signal indicates that the shutters are considered opened. During routine operation (FE/Beamline is ON LINE), shutters are considered closed if they are inserted, as indicated by their limit switches.

ACIS and PSS independently monitor shutter positions through dedicated redundant limit switches.

1.3. FE/Beamline Mode to PSS and ACIS

This signal is derived from a two-position key-operated selector switch labeled "OFF LINE" and "ON LINE" and located in a control panel at each Front End. The switch has four normally open (NO) sets of contacts - two for the ACIS's Chains A and B, and two for the PSS. The signal is asserted in the "ON LINE" position, which means that the Beamline is ready to accept photons if the PSS is complete.

In the "OFF LINE" position, the Beamline cannot accept photons under any circumstances, and the shutters must be closed. The "OFF LINE" mode is implemented to allow independent installation, testing, and maintenance of Beamline equipment without interfering with the operation of the Storage Ring.

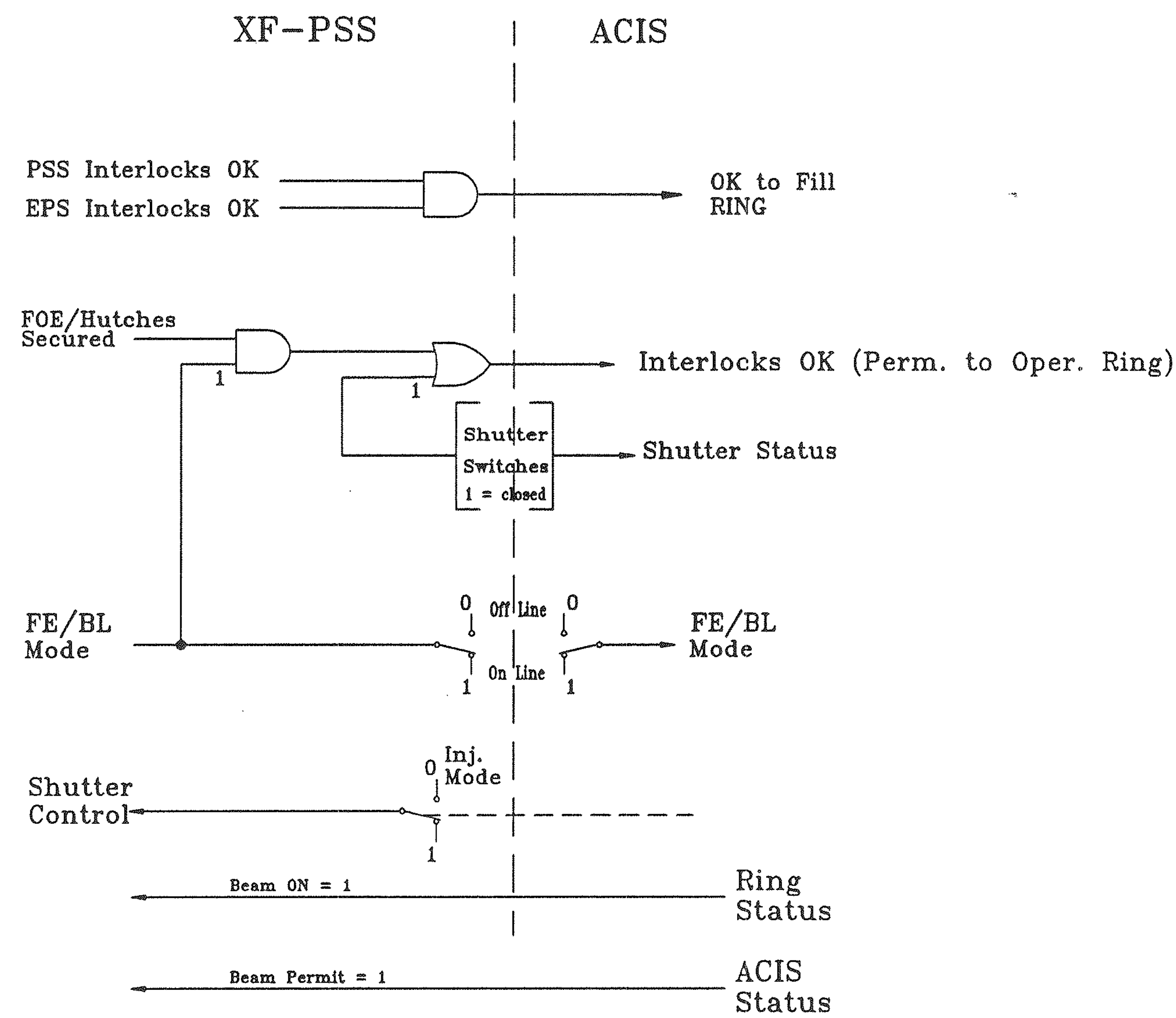

Fig. 9 XF-PSS to Storage Ring ACIS Interface Signals

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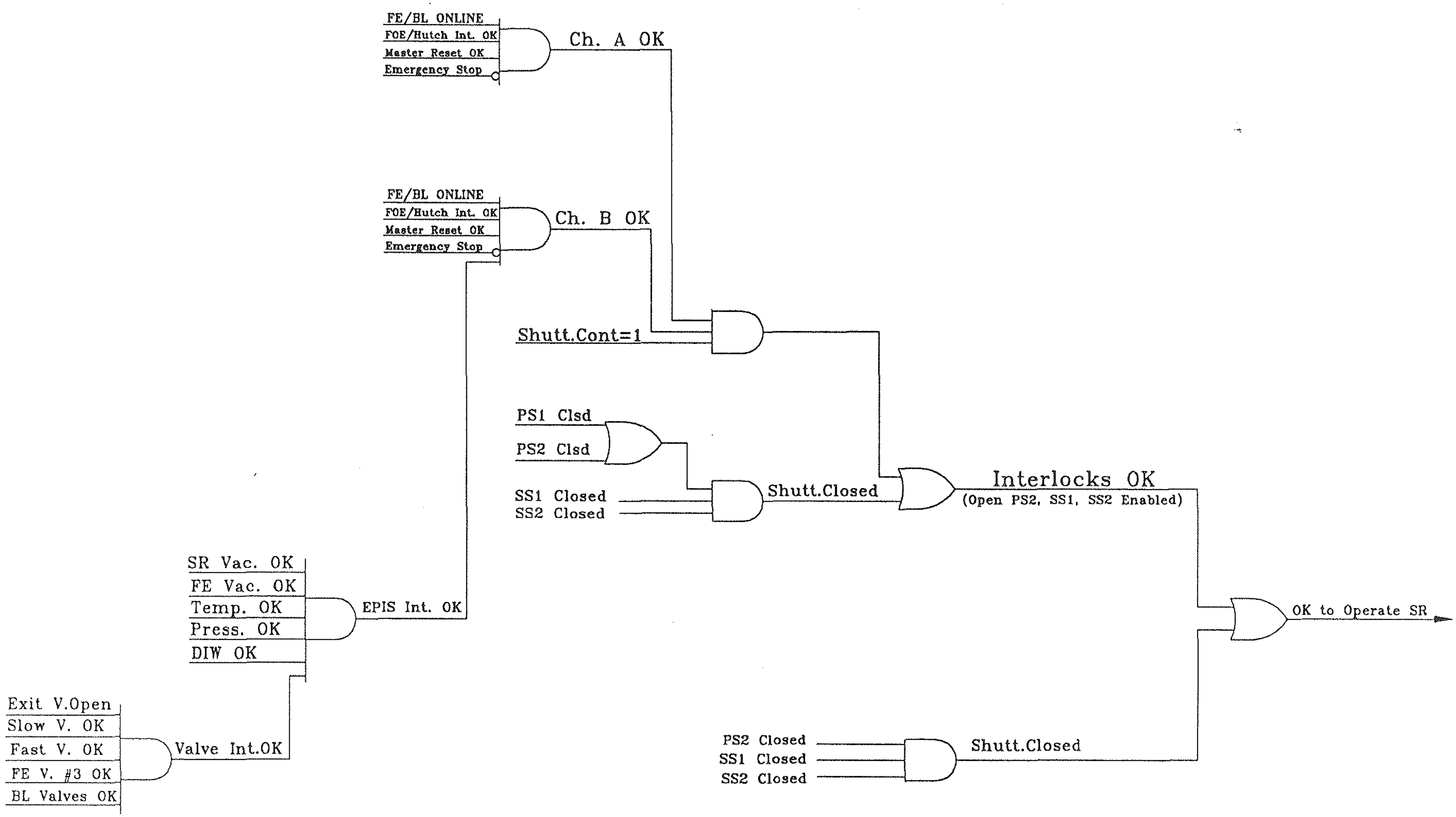

Fig. 10 Ring Beam Permit Logic

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1.4. Operating Modes

Each Beamline is either "ON LINE" or "OFF LINE". If it is "OFF LINE", the shutters are unconditionally closed and deenergized.

If "ON LINE", the control of the shutters is determined by the following Storage Ring operating modes:

1.4.1. Storage Ring Fill Mode

When the Storage Ring is being filled, the Front End shutters are closed.

1.4.2. Stored Beam Mode

After the Storage Ring is filled and stable orbit is attained, control of the shutters is transferred to the individual Beamlines. The shutters may now be opened, provided PSS interlocks are all made up.

1.4.3. Top-off Mode

This mode allows low beam currents to be injected into the Storage Ring without closing the shutters.

1.5. ACIS/PSS "ON LINE" Operation

When a Beamline is "ON LINE", it may receive photons from the Storage Ring. Therefore, it is imperative that the Personnel Safety System is fully functional. Because operational reliability is a prime concern, it is important to only trip the stored beam when danger to personnel exists. The PSS interlock scheme described below maintains a high level of safety while limiting the possibility of an unnecessary beam dump.

When PSS detects an unsafe condition, the following events occur.

a) The PSS immediately commands the Front End Second Photon Shutter to close.

b) Timers start running on both chains. Unless both chains see PS2 closed within 1 sec., the PSS inserts the First Photon Shutter.

c) Once PS2 or PS1 is IN, the Safety Shutters close. Unless both chains see at least one Photon Shutter and both Safety Shutters closed within the allotted time, the PSS Status signal to the ACIS is dropped, and stored beam is dumped. If both chains detect closed shutters within the timeout period, the PSS Status signal remains asserted.

d) PSS latches the event and notifies the Control Room about the occurrence through the EPICS system. Experimenters are prevented control of the shutters until the event is investigated and the interlock is reset by an authorized individual. A Master Reset Key is required for that.

e) Once the cause of the trip is determined and any problems corrected, the Beamline can be returned to normal operation.

f) If the stored beam was tripped, once the shutters to the offending Beamline close, beam can be injected into the Storage Ring to bring the other experimenters back on line.

1.6. ACIS/PSS "OFF LINE" Operation

By switching a Beamline "OFF LINE", installation, testing, and maintenance may be performed without interfering with the operation of the Storage Ring. Because the PSS is essentially out of service, it is vitally important that the Front End shutters are closed and cannot be opened. Therefore, when the selector switch is in the "OFF LINE" position, the pneumatic power to the shutters will be disabled and locked out. If a Beamline is "OFF LINE" and ACIS detects any of the Beamline shutters open, the beam will immediately be dumped.

It has been mentioned above that different power supply systems are electrically isolated by electromechanical relays. Figure 11 on the next page shows the schematic diagram. Relay bank K1 - K5 is installed in the BM Front End equipment rack, whereas bank K6 - K10 is at the ID Front End.

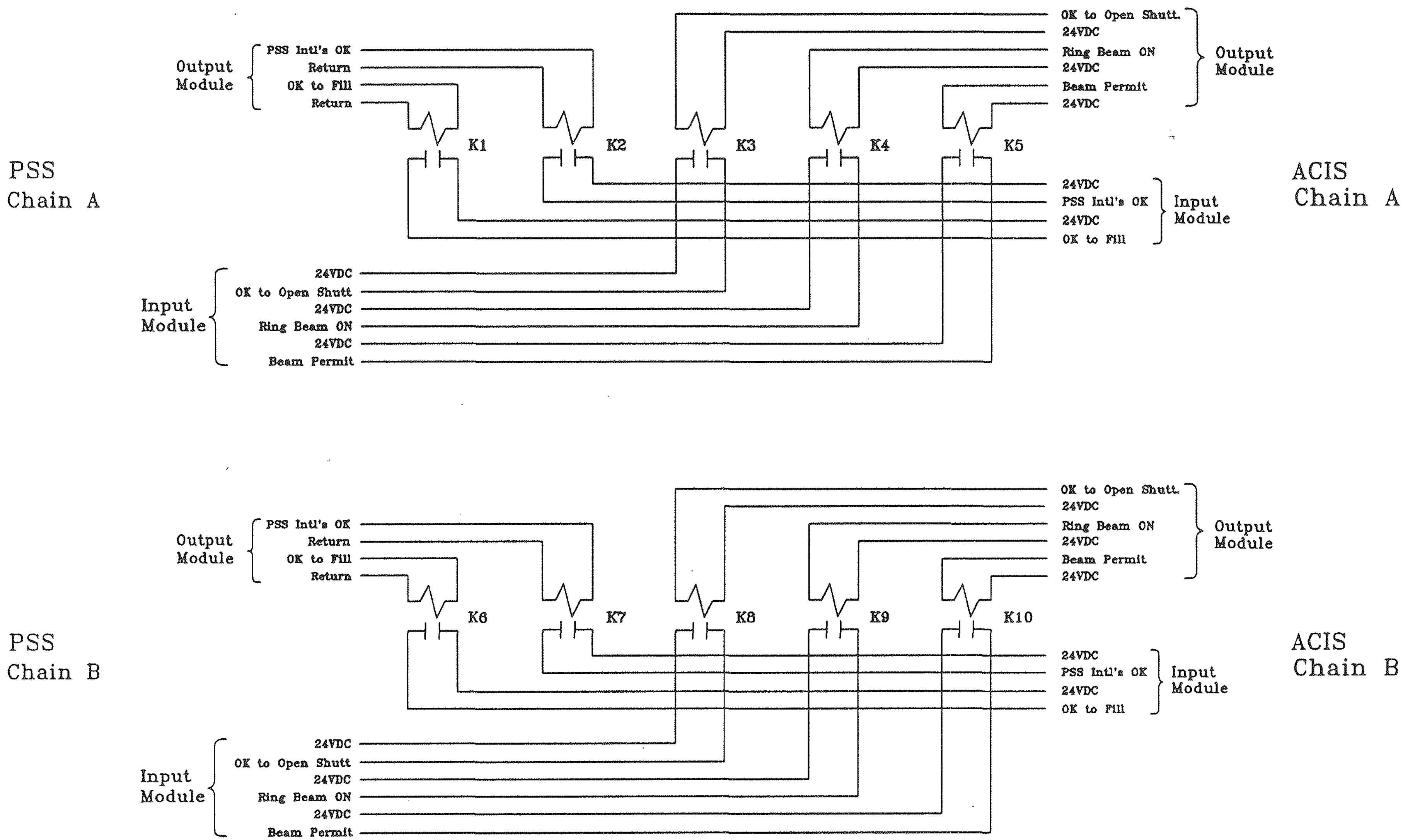

Fig. 11 PSS to ACIS Interface Wiring

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2. Interface between PSS and Storage Ring Controls

The Experimental Floor Personnel Safety System interacts with the accelerator Main Control System for two reasons: to bring information about individual Beamline interlocks to the Main Control Room, and to be able to abort stored e^+ beam when there is danger of personnel being exposed to high levels of x-ray radiation.

2.1. PSS to EPICS Interface

This issue is discussed in detail in J. Stein's report "PSS Status Reporting in the Control Room"[2]. Only a narrative of the subject is given in this paper.

There are two reasons for this interface: (a) to bring information about all sector interlocks to the Main Control Room, and (b) to provide a mechanism for reporting interlock trips.

Having interlock status displayed at a central location will facilitate the work of the PSS System Manager and people involved with the system. The arrangement will also be useful to the accelerator operators.

In the event of an interlock system trip, Sector PSS will record and store all relevant information. In addition, the event will also be reported to the Control Room.

Each chain interfaces to EPICS (Experimental Physics and Industrial Control System) independently. Twinax cable ties a direct communication module (DCM) located in the PLC's main rack to an Allen-Bradley's Scanner Module located in the VME/VXIbus enclosure - Input/Output Controller (IOC). IOC contains Motorola 68040 SBC frontend computer. The 68040 is a 32-bit single-board μ-processor with 4MBytes DRAM. In addition to its CPU functions, the module also serves as VME system controller and Ethernet controller. The IOC runs under VXWorks. It connects to the backbone Ethernet via a half-card transition module.

Workstations and X terminals using a UNIX operating system serve as operator interfaces (OPI). Status screens are built to provide an overall view of all the Sectors with LED-type indicators showing interlock status. By clicking a mouse, it is possible to get the next screen for a particular Beamline. The next level allows one to zoom in on an individual FOE or Hutch.

An important feature of the interaction is that only one-way communication is allowed - PLC → EPICS. In order to safeguard against inadvertent altering of the PSS algorithm, EPICS cannot write to the PLC's input image table.

The block diagram in Figure 12 illustrates how the hardware is interconnected.

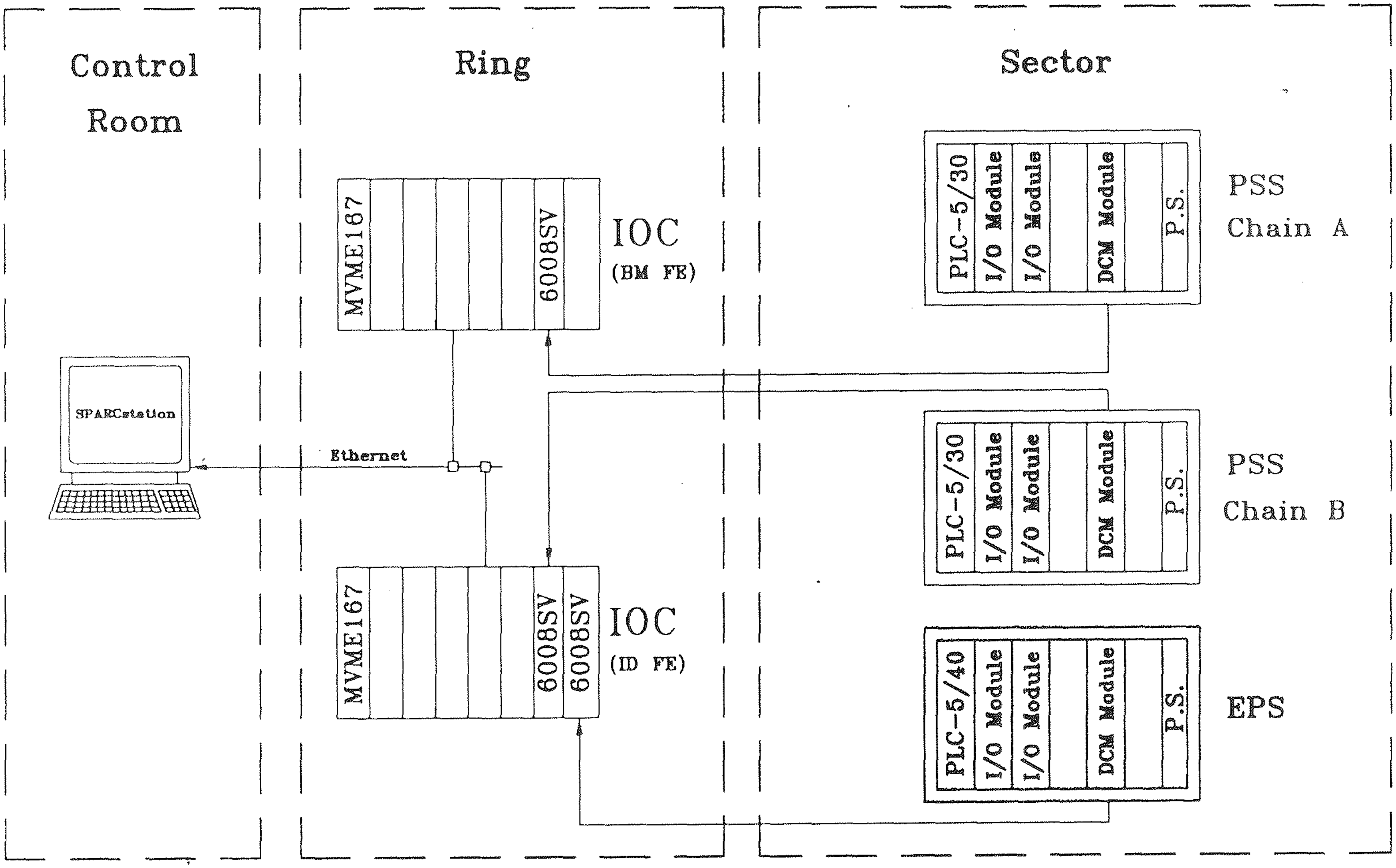

Fig. 12 PSS and EPS Interface to EPICS

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2.2. Interface Between PSS and Storage Ring RF System and Dipole Magnet PS

Under certain conditions, it might become necessary for the stored beam to be dumped by the Experimental Floor Personnel Safety System. To provide the PSS with such capability, a dedicated PSS Beam Abort Interlock System (PSS-BAS) is implemented. The system is PLC-based; it is built around Allen-Bradley PLC hardware. ICOM software is used for programming, documenting, and troubleshooting.

2.2.1. PSS Beam Abort System Hardware

The system hardware consists of PLCs, input modules, output interfaces, backplane power supplies, field device power supplies, uninterruptible power supply, man-machine interface device, electromechanical relays, and emergency beam stop buttons.

a) A **PLC-5/30 Processor** is used. The 5/30 has the following features:

- 32K words base memory
- Battery backed-up RAM for storage of the control algorithm
- EEPROM module memory for storage of the application program
- Internal watchdog timers for checking the integrity of the control program and I/O addresses. A watchdog fault will deenergize all PLC outputs thus disabling RF and Dipole Magnet Power Supplies operation.
- Complete control program checksum on the ladder logic. This includes all instructions and instruction operands. Should the program become corrupted, a fault bit is set to fault the processor and all outputs are deenergized.

b) The **Isolated Input Module** is a 16-channel optoisolated interface. Each channel has its own return, thus keeping different power supply systems electrically isolated. "OK to Run" signals from the Sector PLCs are wired to this module. Chains A and B use separate input modules.

c) An **Isolated Output Module** interfaces the PLC processor to the relay coils. NO contacts of these relays are being used in the interlock circuits of the RF and dipole magnet power supply systems.

d) An **8A Single Slot Power Supply** resides in the right-most slot of the PLC rack. It supplies TTL level voltage to all PLC components located in the rack. This power supply has nothing to do with the field devices.

e) The **Field Device Power Supply** is a 10A linear regulated AC-DC PS. It provides 24VDC for the operation of relays. One PS is provided for each PSS Beam Abort System Chain. Output voltage and current are indicated on the front panel voltmeter and ammeter.

The system shares the Uninterruptible Power Supply (UPS) and Video Control Panel with other system equipment installed in the same relay racks. More on the PLC hardware is included in the description of the Experimental Floor Personnel Safety System.

2.2.2. Beam Abort System Software

A commercially available software package, ICOM, is used for developing the PLC control program. The software is also used for online and offline troubleshooting, editing, and documenting. Common mode failures are avoided by making the programs for Chains A and B different.

Each Chain's application programs are stored in EEPROM cartridges located on the PLC processor modules. On power-up, the program residing in an EEPROM is automatically uploaded into the 5/30 RAM.

2.2.3. Signal Definition

The following signals are implemented in both interlock Chains

a) **OK to Run RF.** This signal must be asserted for the Storage Ring radio frequency system to run. This is only possible when "OK to Run RF" signals coming in from each Sector are all asserted. If this signal is denied, RF turn-off or rephasing will take place. The circuitry is fail safe, that is the interface relays must be energized to enable the RF.

b) **OK to Run Dipole Magnet PS**

This signal is analogues to the "OK to Run RF".

c) **RF OFF** Signal. The PSS must "know" that, in response to the denial of the "OK to Run RF" signal, controlled equipment has indeed turned off. The PSS is specifically looking for the ON to OFF transition. This input is especially valuable for routine testing of the Beam Abort interface.

d) **Dipole Magnet OFF** Signal - same as c).

A block diagram and the logic of the interface are shown in Figures 13 and 14.

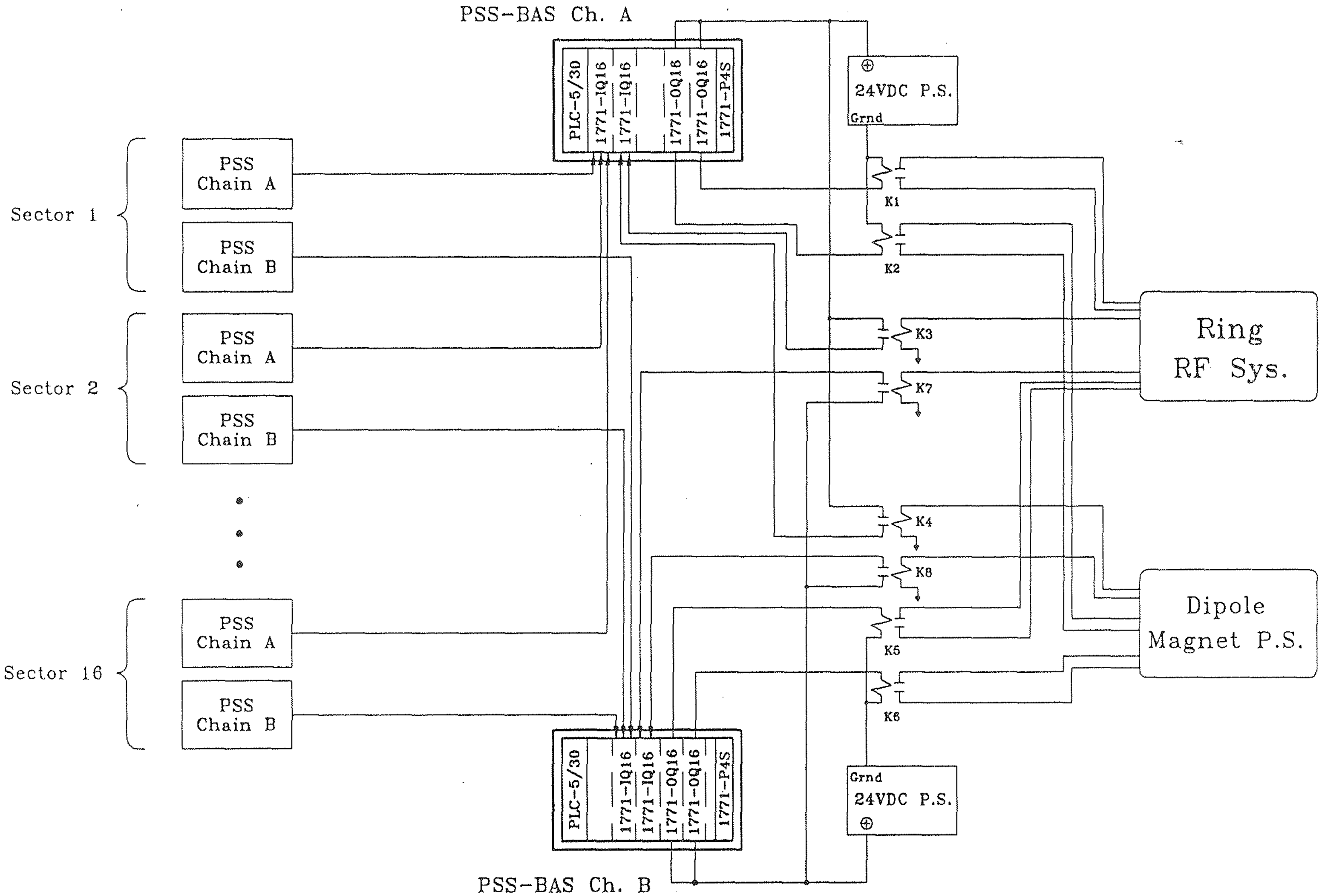

Fig. 13 PSS Beam Abort System (PSS-BAS)

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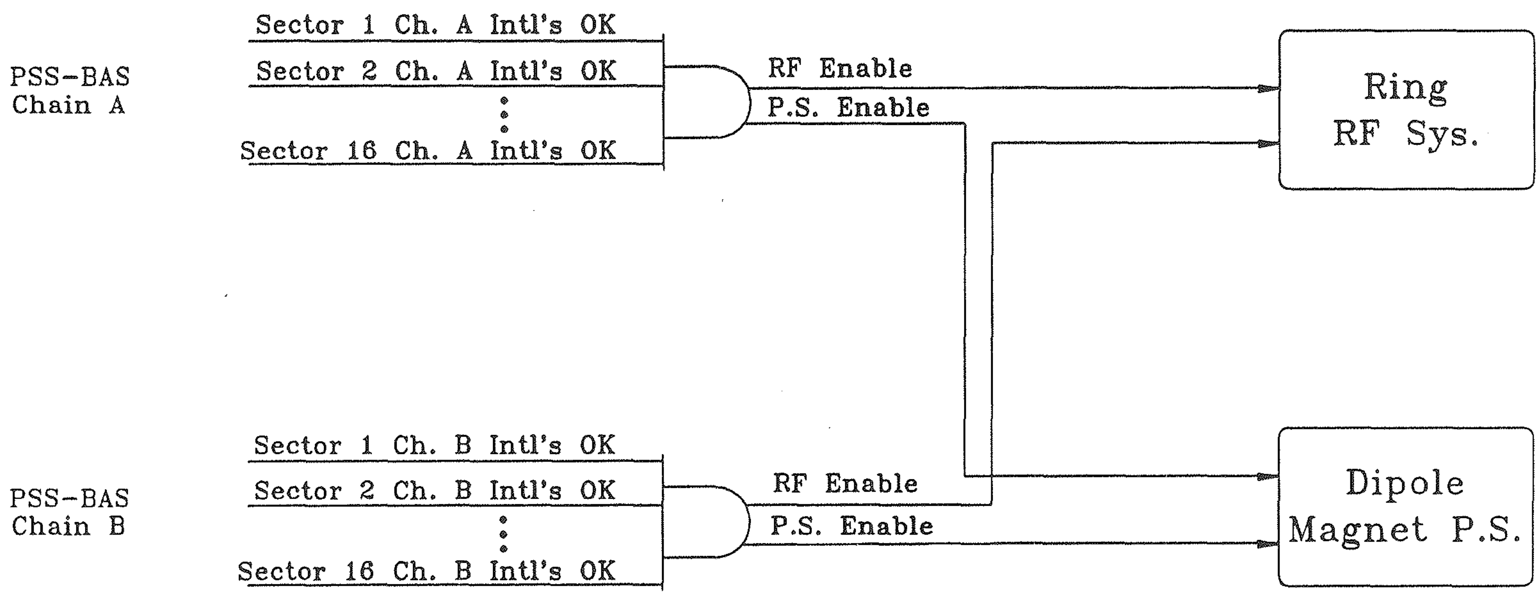

Fig. 14 PSS Beam Enable Logic

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3. **Interface between PSS and EPS**

Data transfer is between EPS and Chain B of the PSS. In order to avoid common ground problems, all interactions are through Isolated Input (1771-IQ16) and Isolated Output (1771-OQ16) Modules.

3.1. PSS to EPS Signals

The Personnel Safety System provides the EPS with information on the mode of the white beam hutches. White beam hutches can be in one of three modes, hence there are three interface signals:

Mono Passthrough Mode
Monochromatic Beam Mode
White Beam Mode

The Equipment Protection System uses this information in the control logic of the Beamline vacuum valves. This way, unnecessary demands on the number of valves that must be closed when accessing vacuum sections are eliminated. A section of a Beamline that has vacuum valves on both ends is a vacuum section.

An example of such sections are sections 6 and 7 of the 1BM beam transport line and Sections 5 and 6 of the 1ID line (see Figures 15 and 16). Specific requirements on the logic of these sections and associated valves can be found in two charts "Experimental Floor Equipment Protection Matrix for the APS SRI CAT", one for 1BM and another for 1ID. These matrixes are part of the report "Experimental Floor Equipment Protection System".

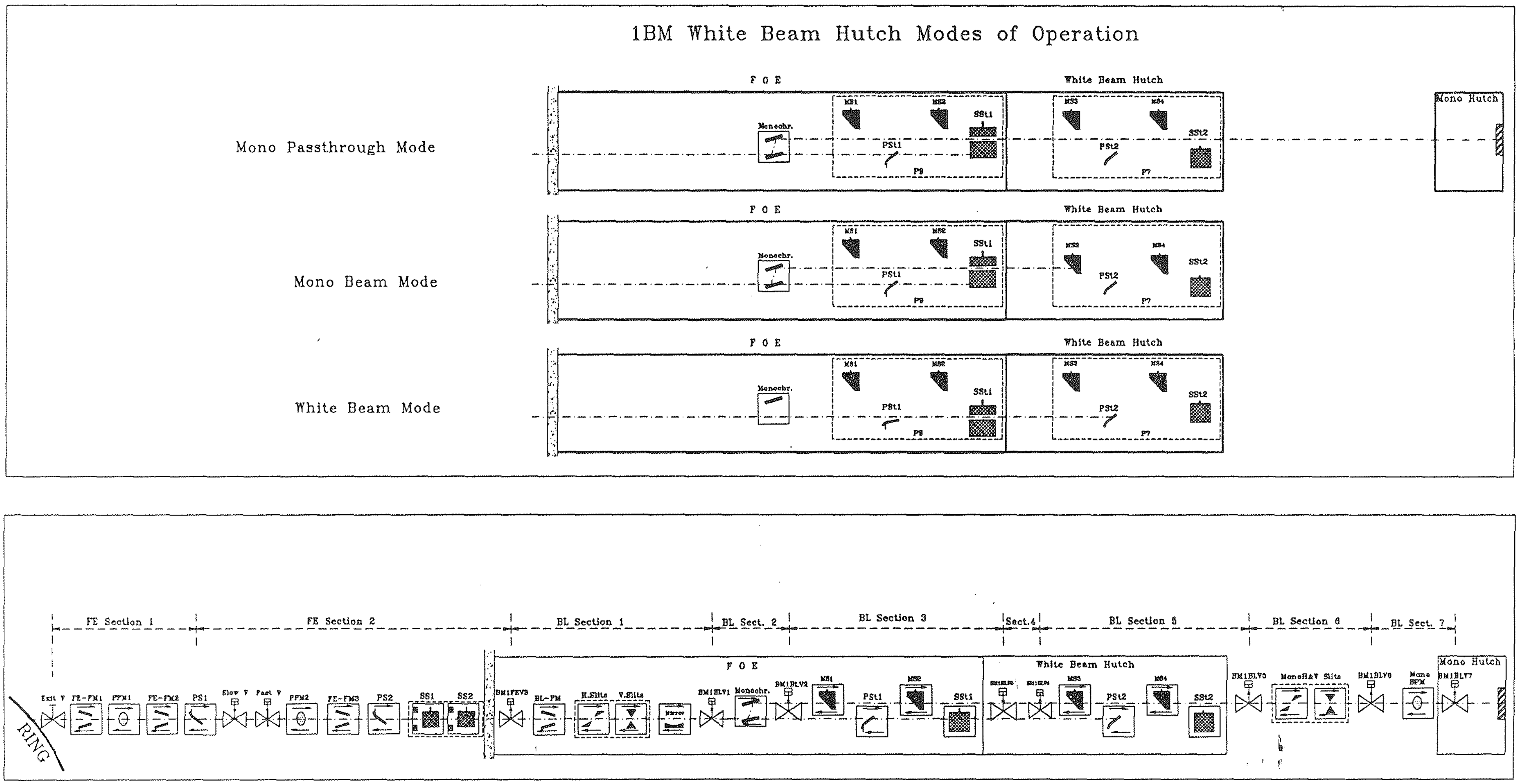

Fig. 15 Schematic Layout of the APS SRI CAT 1BM

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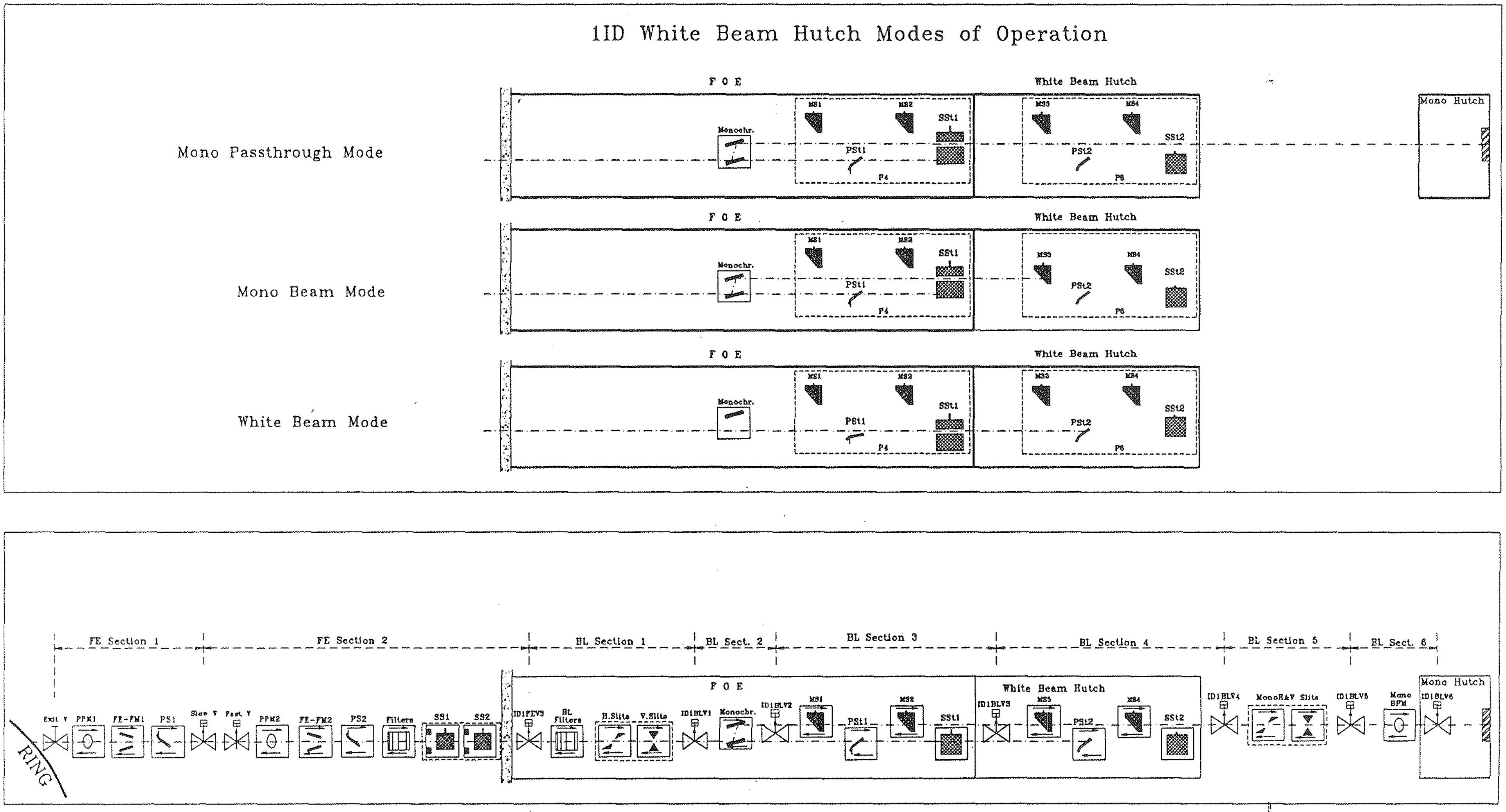

Fig. 16 Schematic Layout of the APS SRI CAT 1ID

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3.2. EPS to PSS Signals

Because PSS has exclusive control over the Front End Second Photon Shutter and Safety Shutters, EPS has to notify PSS whether it is OK to open the FE shutters as far as Sector equipment protection is concerned.

a) **BM FE Equipment Interlocks OK**

This is a summation signal for the status of all Front End devices and Beamline components that directly affect the operation of the Front End. It must be asserted for the Bending Magnet FE PS2, SS1, and SS2 to open. If this input changes to false during the run, PSS automatically inserts FE shutters.

Should a protective device itself (e.g., PS2) lose flow, the First Photon Shutter is used as backup. If neither FE photon shutter is available to protect downstream instrumentation, stored beam is dumped.

b) **BM PS1 Interlocks OK**

Presence of this signal tells PSS that it can count on the First Photon Shutter to back the Second Photon Shutter if needed. If this signal is not asserted (not 1), PSS "knows" that PS1 is not available in its usual backup roll and adjusts its responses accordingly.

c) **ID FE Equipment Interlocks OK**

This interface is analogous to the above item a).

d) **ID PS1 Interlocks OK**

This interface is analogous to item b).

e) **EPS OK to Fill Ring**

This signal must be asserted for the Storage Ring e^+ fill to be possible. This input being false (zero) will not interrupt the run, but will stop Storage Ring refill until the problem is corrected.

To illustrate the point, consider the following possible scenario. The Storage Ring has positron beam, the insertion device gap is closed, the Front End accepts photons, the First Photon Shutter is open, and an experiment is in progress. Suddenly PS1 cooling water flow is detected as being low. The only immediate action necessary is to drop the "EPS OK to Fill Ring" signal (the event is, of course, flagged on an X terminal screen in the Control Room). Should PS1 be triggered to close, normally by the Fast Valve sensor, stored beam is aborted. Otherwise, the run can continue until the natural breaking point - Ring Fill. However, before the Storage Ring can accept positrons again, the flow must be fixed, which will reassert the "EPS OK to Fill Ring" input.

There are many similarities between this and the "PSS OK to Fill Ring" signals.

4. **Interface between EPS and Storage Ring Controls**

There are two objectives in interfacing the Experimental Floor Equipment Protection System to the Main Control System of the Storage Ring: (a) to display the interlock status of all Front End and Beamline components in the Control Room, and (b) to provide means for dumping stored beam should conditions for equipment damage develop.

4.1. EPS to EPICS Interface

Joshua Stein addressed the subject in detail in the document titled "EPS Status Reporting in the Control Room"[3]. Briefly, however, the idea is to have a central location from which any of a Sector's interlocks can be checked. Screens will be built on a UNIX workstation or an X terminal to provide an overhead view of all Sectors with the means of zooming in on a particular Front End/Beamline and Beamline Section by clicking a mouse. Alphanumeric messages and LED-type displays will allow personnel responsible for equipment protection as well as Control Room operators to quickly assess the situation whether for information gathering only or when action is required.

In addition to the graphic displays, screens will be created to show various interlocks in a table format. Data will be sorted by function (that is temperature, flow, and air pressure will be in separate charts), as well as by FE/Beamline devices. The later will allow checking a device for all the interlocks associated with it.

As far as equipment protection goes, there are four main modules - flow, temperature, compressed air pressure, and vacuum system. Reporting vacuum sensors and valves status through EPICS makes it easy to interrogate any Sector's vacuum system without having necessarily to walk to the Sector's local controls. Troubleshooting time is greatly reduced.

Additional benefits of the EPS $\Rightarrow$ EPICS interface are expected from the fact that the Sector Equipment Protection System will be able to control Front End and Beamline instrumentation that is strictly in the EPICS environment. For example, EPICS can initiate opening of an insertion device (ID) by communicating to the ID drives when a trigger signal is received from EPS.

A block diagram of this interaction is shown in Fig. 12.

4.2. Interface Between EPS and Storage Ring RF and Dipole Magnet PS

The Experimental Floor Equipment Protection System interacts with the Storage Ring Fast Beam Abort System and the Dipole Magnet Power Supply. The Fast Beam Abort System is a front end interlock summation interface to the Ring's Radio Frequency System. EPS to Ring RF and Dipole Magnet PS interface enables the EPS to dump the beam in the Storage Ring should a potential for equipment damage develop.

Each Sector's EPS inputs into the EPS Beam Abort System (EPS-BAS), which in turn connects to the Fast Beam Abort and Dipole Magnet PS (see block diagram in Fig. 17).

4.2.1. EPS Beam Abort System Hardware

System hardware consists of PLC, Input and Output Modules, PLC rack power supply, field device power supply, uninterruptible power supply, and man-machine interface device. All signals pass through relay contacts for electrical isolation.

a) A **PLC-5/30 Processor** (1785-L30B) is used. The 5/30 has the following features:

- 32K words memory
- Battery backed-up RAM for storage of the control algorithm
- EEPROM module memory for storage of the application program
- Internal watchdog timers for checking the integrity of the control program and I/O addresses. A watchdog fault will deenergize all PLC outputs thus disabling RF and Dipole Magnet Power Supplies operation.
- Complete control program checksum on the ladder logic. This includes all instructions and instruction operands. Should the program become corrupted, a fault bit is set to fault the processor and all outputs are deenergized.

b) The **Isolated Input Module** (1771-IQ16) is a 16-channel optoisolated interface. Each channel has its own return thus keeping different power supply systems electrically isolated. "OK to Run" signals from Sector PLCs are wired to this module.

c) An **Isolated Output Module** (1771-OQ16) interfaces the PLC processor to the relay coils. Normally open contacts of these relays are being used in the interlock circuits of the Fast Beam Abort and Dipole Magnet Power Supply Systems.

d) An **8A Single Slot Power Supply** (1771-P4S) resides in the right-most slot of the PLC rack. It supplies TTL level voltage to all PLC components located in the rack. This PS has nothing to do with the field devices.

e) The **Field Device Power Supply** is a 10A linear regulated AC-DC PS. It provides 24VDC for the operation of relays. This PS is dedicated to the EPS Beam Abort System. Output voltage and current are indicated on the front panel voltmeter and ammeter.

The system shares the UPS and video control panel with other system equipment installed in the same equipment racks.

4.2.2. Beam Abort System Software

A commercially available software package, ICOM, is used for developing the PLC control program. The software is also used for online and offline troubleshooting, editing, and documenting.

The application program is stored in EEPROM cartridges located on the PLC processor module. On power-up, the program residing in an EEPROM is automatically uploaded into the 5/30 RAM.

4.2.3. Signal Definition

a) **RF Enable.** This signal must be asserted for the Storage Ring's radio frequency system to run. This is only possible when "Interlocks OK" signals coming in from each Sector are all asserted. If this signal is denied, the Fast Beam Abort interlock chain is not complete and RF turn-off or rephasing will take place. The circuitry is fail safe, that is the interface relays must be energized to enable the RF.

b) **Magnet PS Enable.** This signal is analogous to the "RF Enable".

c) **RF OFF** Signal. The EPS must "know" that in response to the denial of the "RF Enable" signal, controlled equipment has indeed turned off. EPS is specifically looking for the transition from ON to OFF. This input is very useful during the testing of the Beam Abort interface.

d) **Magnet PS OFF** Signal - the same as item c).

The logic of the interface is shown in Figure 18.

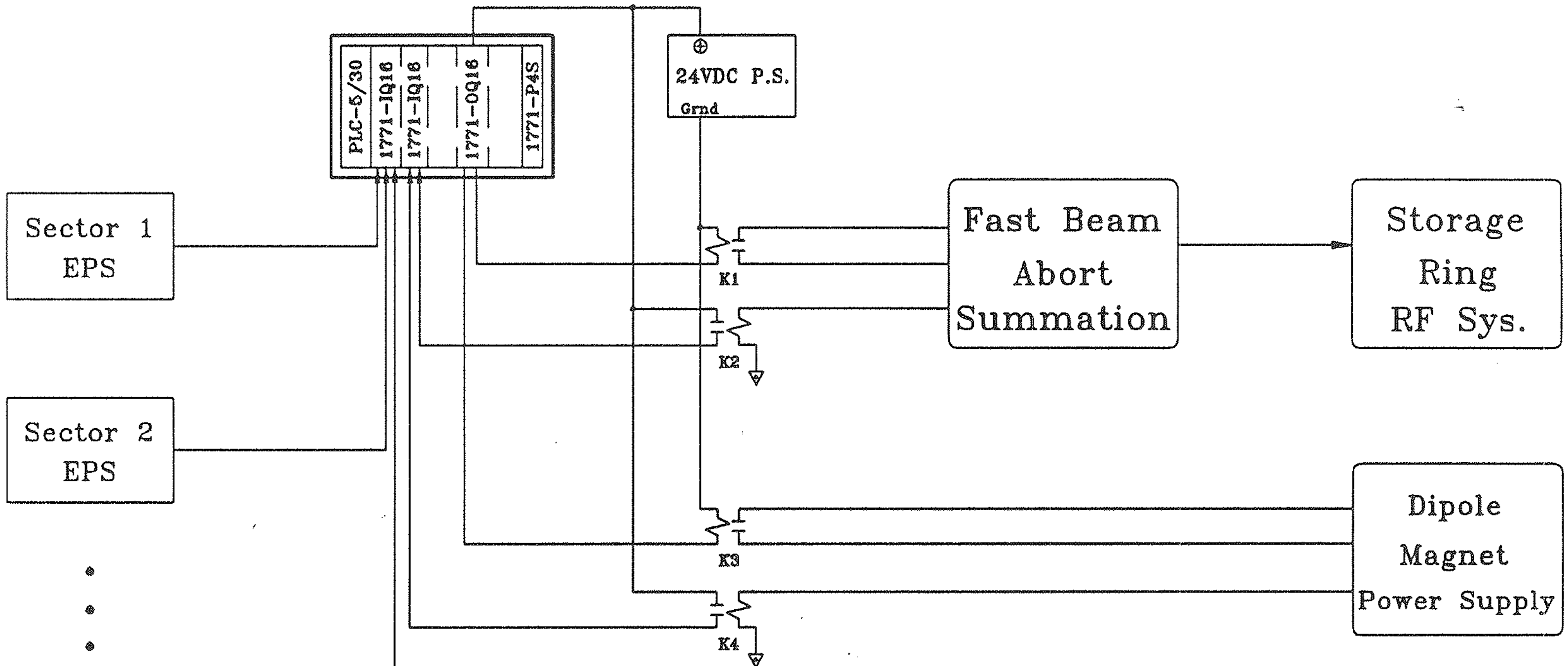

Fig. 17 EPS Beam Abort System (EPS-BAS)

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[acad]drawings\AbortEPS.dwg

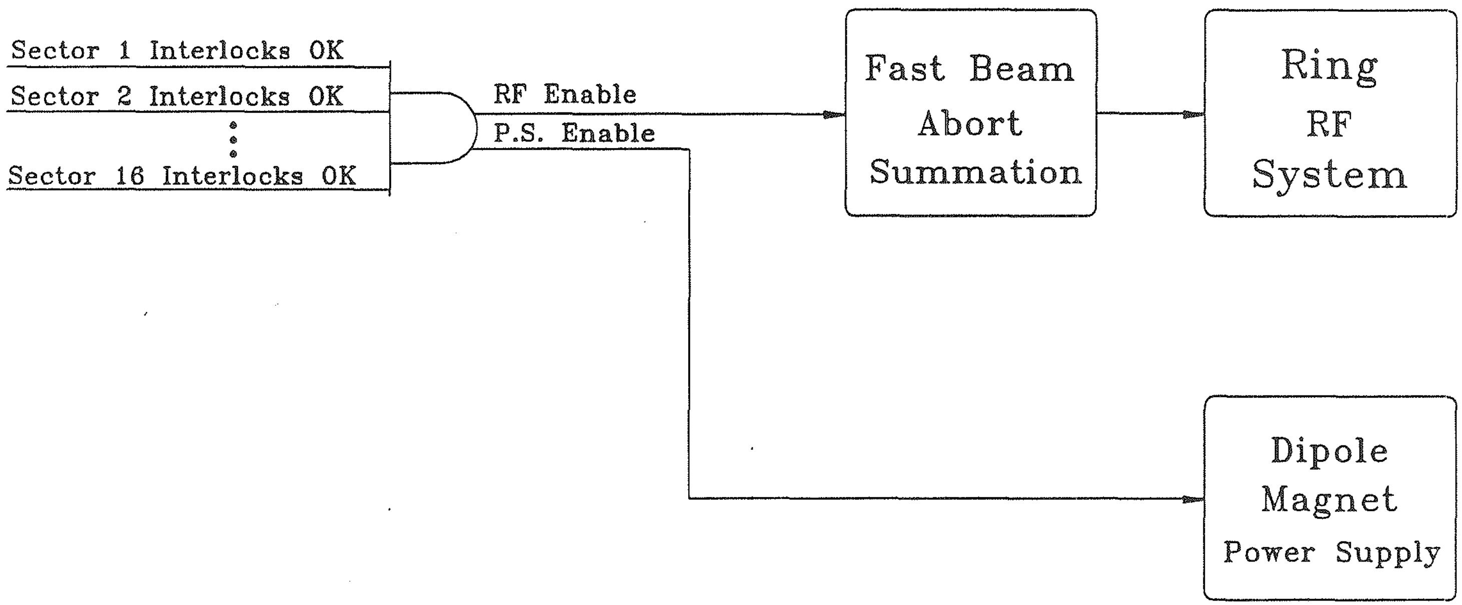

Fig. 18 EPS Beam Enable Logic

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[acad]drawings\BEnable1.dwg

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VII. REFERENCES

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